BYSMALITHS.

A LACCOLITH as defined by Gilbert[1] is a body of igneous rock which has forced itself by intrusion, in a molten condition, between strata of sedimentary rocks in such a manner as to have lifted the overlying strata in a dome-shaped arch above it. The arching strata may be stretched and cracked to variable degrees and the molten magma may penetrate them to a greater or less extent according to the character of the rocks and the amount of cracking. A symmetrical dome may be the ideal form of a laccolith, but as Cross[2] has shown is rarely assumed because of the many modifying conditions attending the process. The principal ones are: a position of the plane of fracture along which intrusion takes place oblique to the bedding of the strata; lines of structural weakness in the strata; the presence of earlier intrusive bodies; the lack of coherence and of pronounced bedding in the strata invaded. Gilbert's use of the term laccolith embraced all lenticular bodies of igneous, intrusive rock occurring in stratified sedimentary rocks.

A laccolith is to be distinguished from an intrusive sheet of igneous rock, which also has been in most cases intruded between strata that were more or less horizontal at the time and required to be lifted by the force within the molten magma. The difference lies in the thickening of the igneous body into a more or less lenticular mass in the case of the laccolith, and in its retaining an almost uniform thickness in that of a sheet. In both cases the act of lifting the superincumbent strata must have been due to the same kind of force, namely, that exerted by a liquid under pressure upon the sides of a containing reser-

[1] GILBERT, G. K., Report on the geology of the Henry Mountains, U. S. Geog. and Geol. Surv. of the Rocky Mountain region, J. W. POWELL in charge. Washington, 1877.

[2] CROSS, W., The Laccolithic Mountain Groups of Colorado, Utah, and Arizona. 14th Ann. Rep. of the Director of the U. S. Geol. Surv., pp. 236. Washington, 1895.

voir. The difference in the results must be occasioned either by differences in the direction and rate of the intrusion, or by variations in the resistance offered by the overlying rocks. A sudden vertical thrust may lead to the arching of the strata immediately above its point of application. Local weakness of the strata may cause their elevation in particular places, as remarked by Cross. Another cause undoubtedly lies in the initial arching of strata brought about by other dynamic forces tending to bend and dislocate rocks. Such movements may be accompanied by extravasation of molten magmas which will follow planes of weakness in the dislocated rocks and will force themselves most readily where the rocks offer least resistance to displacement.

There is nothing in the petrographical characters of the rocks of intruded sheets and laccoliths in general to indicate any physical difference in the molten magmas from which each may have been formed. In both instances the magmas may have been equally liquid at the time of intrusion, or may have had similar compositions.

As regards their shape, it may also be noted that in sheets the lateral dimensions are very great in comparison with their thickness, whereas in laccoliths the thickness is much nearer the lateral dimensions.

Cross has shown that a certain amount of vertical displacement of the overlying strata may accompany their arching without changing the general character of the intruded body as in the laccolith of Mount Marcellina in West Elk Mountains, Colorado.[1] But, when vertical displacement with faulting is one of the chief characteristics of the intrusion, a distinction from normal laccolithic intrusion should be recognized. In the extreme this would result in the forcing upward of a more or less circular cone or cylinder of rock, which might be driven out at the surface of the earth, not necessarily in a coherent condition, or might be arrested at any stage of such extrusion and so might terminate in a dome of strata resembling the dome over a lacco-

[1] Loc. cit., pp. 182 and 236.

lith. By this mode of intrusion, the vertical dimension of the intruded mass becomes still greater as compared with the lateral dimensions, so that its shape is more that of a plug or core. Such an intruded plug of igneous rock may be termed a *bysmalith* (βύσμα = plug, λίθος = stone). There is then a transition from a flat, intrusive sheet to a laccolith with lenticular form, and from this to a bysmalith with much greater depth and considerable vertical displacement.

The resemblance of a bysmalith to a stock of igneous rock is such as to suggest at first their identity or close relationship. And though bodies of igneous rock may occur whose character might lead to their being classed with either of these types of intrusion, nevertheless it will be found advantageous to discriminate between bysmalith and stock by limiting the term stock to such bodies as occupy nearly vertical tubes or funnels of indefinite depth in rocks of any and all kinds, massive, schistose or stratified, and which maintain such a relation to them as to appear to belong to the category of dikes. Such tubes or funnels have been produced most probably by the enlargement of a fissure or a cluster of fissures by the carrying up of fragments torn from the walls. Stocks frequently represent the filling of a channel through which successive eruptions of magma have passed, as the conduit of a volcano. The formation of a bysmalith is more properly one act of eruption, and the solid rock removed is a block of nearly horizontal strata lifted at one time.

Examples of bysmaliths have not been described as such to any extent so far as the writer knows. Russell[1] has called attention to what he considers volcanic plugs in the region of the Blacks Hills of South Dakota and has suggested their recognition as types of intrusions different from laccoliths. But in his description of them he has mentioned nothing that demonstrates or even indicates that they possess the character of a plug. In each case they may be central remnants of small laccoliths. This is made probable by the position of the prismatic columns, which would be vertical in the central part of a laccolith, whereas

[1] RUSSELL, I. C., JOUR. GEOL., Vol. IV, p. 23.

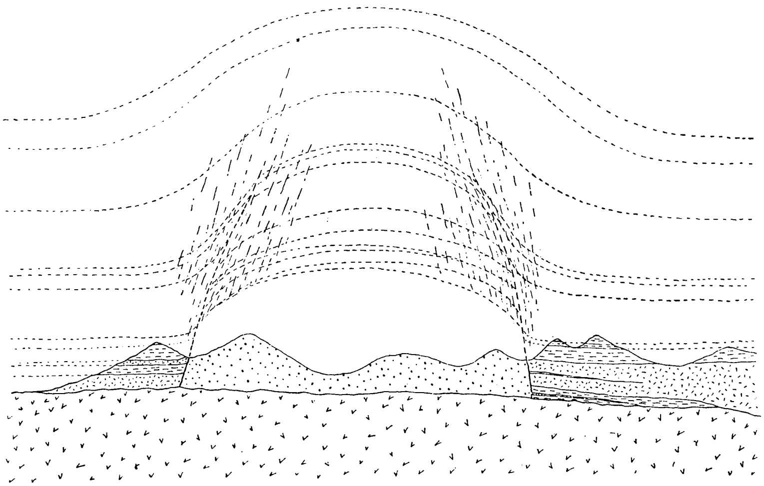
they should be horizontal in the body of a volcanic plug, and only vertical in the central part of its summit. In the case of Inyan Kara, mentioned by Russell, the dip of the limestone in the encircling wall, taken in connection with the diameter of the circle and the elevation of the igneous rock, is just what it might have been, had the igneous mass been a laccolith. The occurrences mentioned by Russell cannot be considered as illustrations of volcanic plugs without further evidence of their relations to the surrounding rocks.

In the Yellowstone National Park[1] at the southern end of the Gallatin Mountains, a great body of dacite-porphyry, three miles long and two miles wide, forms Mount Holmes and a group of mountains at the head of Indian Creek. In vertical extent the exposure of this mass is in all 2300 feet and throughout the exposure the character of the rock is so uniform as to indicate its being one mass solidified at one time.

Three quarters of the circumference of this igneous mass is in contact with stratified rocks, whose general position is nearly horizontal, but which in the immediate vicinity of the intruded body are bent abruptly upward, dipping away from it at steep angles. In several places the character of the contact plane is well shown, especially on the south side of the Dome, where a nearly vertical contact can be traced for almost a thousand feet. In each case the contact plane is almost vertical, inclining away from the intruded mass. From this mass small veins of igneous rock have penetrated the adjacent stratified rocks. The latter contained a large intruded body of andesite-porphyry in the form of a laccolith when the magma of the dacite-porphyry was intruded. The western boundary of the Holmes mass lies against gneiss and along a fault plane. An opening on this fault plane was probably the conduit through which the molten magma rose, for similar rock occurs along this fault line three miles to the north. While we have at present no knowledge of the configu-

[1] Geologic Atlas of the United States, Yellowstone National Park Folio, Areal Geology, Gallatin Sheet, Washington, 1896. See also the forthcoming monograph 32 of the U. S. Geological Survey on the Geology of the Yellowstone National Park chap. i.

ration of the bottom of the igneous mass, it seems quite probable that the magma spread in the shaly beds at the base of the Cambrian strata immediately over the nearly horizontal surface of the gneiss and beneath the laccolith already mentioned. The



Ideal section of the Holmes bysmalith.

thickening of the laccolith to the north and its contact with gneiss to the east may have hindered the further spreading of the later magma, resulting in a rupture of the overlying rocks in a block which was lifted by the intruding magma. The area of the block was more than five square miles and the vertical displacement more than 2000 feet, probably more than twice that height. Owing to the nearly uniform, crystalline character of the rock constituting the Holmes bysmalith, the grain being larger than that of the rock of the adjoining laccolith, there is little doubt that it solidified beneath a covering of strata. The slope of the planes of contact indicate that the intruded body possessed a steep dome shape, and the nearly horizontal position of the surrounding sedimentary rocks, at a little distance from the igneous body, prove that the arching of the strata took place at

a much higher horizon in the sedimentary terrane. The total thickness of beds, that were most probably superimposed on the gneiss at the time of the eruption under discussion, is about 9000 feet. These were lifted more than 2300 feet, possibly 4000 feet, and the position of the strata after the intrusion may have been similar to that shown in the accompanying figure, which corresponds in scale to the Holmes bysmalith. The section passes through Mount Holmes and Echo Peak, and does not intersect the conduit.

A more complex body of igneous rock closely related to a bysmalith occurs six miles farther north in the Gallatin Mountains at Gray Peak. It has broken across the strata and has forced into them numerous sheets of igneous rock. It is exposed at a much higher horizon than the Holmes bysmalith, cutting the Dakota conglomerate of the Cretaceous. Its position with regard to adjoining strata is not so well shown as in the case first described, however enough is exposed to prove its plug-like character.

It is probable that this type of intrusion will not be found to be as frequent as the laccolith, just as the latter is much less common than the intruded sheet.

The term *bathylith* has been proposed by Suess[1] for an intruded body having a more or less lenticular shape, which he considered to have been formed by intrusion of molten magma into a previously existing cavity made by the crumpling of the earth's crust. But, as Zirkel[2] has pointed out, the only difference between the bathylith of Suess and the laccolith of Gilbert lies in their mode of formation, their shapes being similar. It is questionable whether bathyliths defined in this strict manner exist. Indeed they probably do not. There has been a tendency among American geologists to use the term bathylith in a different sense from that in which Suess originally used it. This has been expressed by Dana[3] in his *Manual of Geology* in discussing the

[1] SUESS, E., Das Antlitz der Erde. Vienna, 1892, p. 219.

[2] ZIRKEL, F., Lehrbuch der Petrographie. Leipzig, Vol. I, p. 548.

[3] DANA, J. D., Manual of Geology, Fourth Edition, 1895, p. 811.

"granite-core" of the Sierra Nevada, California. "Such a mass of crystalline rock having irregular or indefinite outline has received the name of bathylith." This resembles the definition of stock given by Zirkel,[1] namely "stocks are irregular masses of considerable dimensions which, traversing the adjacent rocks without regard to their position, occur both in the stratified and massive terranes." However, it seems desirable to limit *stock* in the manner already suggested.

There is need for some general term that may be applied to large bodies of intruded rock whose exact character may not be evident, whose lateral extension may be quite irregular and whose depth may be profound. For such indefinite bodies the term bathylith may well be employed.

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[1] Loc. cit., p. 544.